

**e**

$$J = \frac{1}{2}$$

## e MASS (atomic mass units u)

The primary determination of an electron's mass comes from measuring the ratio of the mass to that of a nucleus, so that the result is obtained in u (atomic mass units). The conversion factor to MeV is more uncertain than the mass of the electron in u; indeed, the recent improvements in the mass determination are not evident when the result is given in MeV. In this datablock we give the result in u, and in the following datablock in MeV.

VALUE (10 <sup>-6</sup> u)	DOCUMENT ID	TECN	COMMENT
<b>548.57990946±0.00000022</b>	MOHR 12	RVUE	2010 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •			
548.57990943±0.00000023	MOHR 08	RVUE	2006 CODATA value
548.57990945±0.00000024	MOHR 05	RVUE	2002 CODATA value
548.5799092 ±0.0000004	1 BEIER 02	CNTR	Penning trap
548.5799110 ±0.0000012	MOHR 99	RVUE	1998 CODATA value
548.5799111 ±0.0000012	2 FARNHAM 95	CNTR	Penning trap
548.579903 ±0.000013	COHEN 87	RVUE	1986 CODATA value

1 BEIER 02 compares Larmor frequency of the electron bound in a <sup>12</sup>C<sup>5+</sup> ion with the cyclotron frequency of a single trapped <sup>12</sup>C<sup>5+</sup> ion.

2 FARNHAM 95 compares cyclotron frequency of trapped electrons with that of a single trapped <sup>12</sup>C<sup>6+</sup> ion.

## e MASS

2010 CODATA (MOHR 12) gives the conversion factor from u (atomic mass units, see the above datablock) to MeV as 931.494 061 (21). Earlier values use the then-current conversion factor. The conversion error dominates the uncertainty of the masses given below.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>0.510998928±0.000000011</b>	MOHR 12	RVUE	2010 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.510998910±0.000000013	MOHR 08	RVUE	2006 CODATA value
0.510998918±0.000000044	MOHR 05	RVUE	2002 CODATA value
0.510998901±0.000000020	3,4 BEIER 02	CNTR	Penning trap
0.510998902±0.000000021	MOHR 99	RVUE	1998 CODATA value
0.510998903±0.000000020	3,5 FARNHAM 95	CNTR	Penning trap
0.510998895±0.000000024	3 COHEN 87	RVUE	1986 CODATA value
0.5110034 ±0.0000014	COHEN 73	RVUE	1973 CODATA value

3 Converted to MeV using the 1998 CODATA value of the conversion constant, 931.494013 ± 0.000037 MeV/u.

4 BEIER 02 compares Larmor frequency of the electron bound in a <sup>12</sup>C<sup>5+</sup> ion with the cyclotron frequency of a single trapped <sup>12</sup>C<sup>5+</sup> ion.

5 FARNHAM 95 compares cyclotron frequency of trapped electrons with that of a single trapped <sup>12</sup>C<sup>6+</sup> ion.

$$(m_{e^+} - m_{e^-}) / m_{\text{average}}$$

A test of CPT invariance.

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<8 × 10 <sup>-9</sup>	90	6 FEE 93	CNTR	Positronium spectroscopy
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<4 × 10 <sup>-8</sup>	90	CHU 84	CNTR	Positronium spectroscopy

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$^6$ FEE 93 value is obtained under the assumption that the positronium Rydberg constant is exactly half the hydrogen one.

### $|q_{e^+} + q_{e^-}|/e$

A test of *CPT* invariance. See also similar tests involving the proton.

VALUE	DOCUMENT ID	TECN	COMMENT
$< 4 \times 10^{-8}$	7 HUGHES	92	RVUE
<b>• • •</b> We do not use the following data for averages, fits, limits, etc. <b>• • •</b>			
$< 2 \times 10^{-18}$	8 SCHAEFER	95	THEO Vacuum polarization
$< 1 \times 10^{-18}$	9 MUELLER	92	THEO Vacuum polarization
7 HUGHES 92 uses recent measurements of Rydberg-energy and cyclotron-frequency ratios.			
8 SCHAEFER 95 removes model dependency of MUELLER 92.			
9 MUELLER 92 argues that an inequality of the charge magnitudes would, through higher-order vacuum polarization, contribute to the net charge of atoms.			

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### **e MAGNETIC MOMENT ANOMALY**

#### $\mu_e/\mu_B - 1 = (g-2)/2$

VALUE (units $10^{-6}$ )	DOCUMENT ID	TECN	CHG	COMMENT
<b>1159.65218076 ± 0.00000027</b>	MOHR	12	RVUE	2010 CODATA value
<b>• • •</b> We do not use the following data for averages, fits, limits, etc. <b>• • •</b>				
1159.65218073 ± 0.00000028	HANNEKE	08	MRS	Single electron
1159.65218111 ± 0.00000074	10 MOHR	08	RVUE	2006 CODATA value
1159.65218085 ± 0.00000076	11 ODOM	06	MRS	— Single electron
1159.6521859 ± 0.0000038	MOHR	05	RVUE	2002 CODATA value
1159.6521869 ± 0.0000041	MOHR	99	RVUE	1998 CODATA value
1159.652193 ± 0.000010	COHEN	87	RVUE	1986 CODATA value
1159.6521884 ± 0.0000043	VANDYCK	87	MRS	— Single electron
1159.6521879 ± 0.0000043	VANDYCK	87	MRS	+ Single positron
10 MOHR 08 average is dominated by ODOM 06.				
11 Superseded by HANNEKE 08 per private communication with Gerald Gabrielse.				

### $(g_{e^+} - g_{e^-}) / g_{\text{average}}$

A test of *CPT* invariance.

VALUE (units $10^{-12}$ )	CL%	DOCUMENT ID	TECN	COMMENT
<b>= 0.5 ± 2.1</b>	12	VANDYCK	87	MRS Penning trap
<b>• • •</b> We do not use the following data for averages, fits, limits, etc. <b>• • •</b>				
< 12	95	13 VASSERMAN	87	CNTR Assumes $m_{e^+} = m_{e^-}$
22 ± 64		SCHWINBERG	81	MRS Penning trap
12 VANDYCK 87 measured $(g_-/g_+) - 1$ and we converted it.				
13 VASSERMAN 87 measured $(g_+ - g_-)/(g-2)$ . We multiplied by $(g-2)/g = 1.2 \times 10^{-3}$ .				

### **e ELECTRIC DIPOLE MOMENT (d)**

A nonzero value is forbidden by both *T* invariance and *P* invariance.

VALUE ( $10^{-28}$ ecm)	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt; 10.5</b>	90	14 HUDSON	11	NMR YbF molecules
<b>• • •</b> We do not use the following data for averages, fits, limits, etc. <b>• • •</b>				
< 6050	90	15 ECKEL	12	CNTR $\text{Eu}_{0.5}\text{Ba}_{0.5}\text{TiO}_3$ molecules
6.9 ± 7.4		REGAN	02	$^{205}\text{TI}$ beams
18 ± 12 ± 10		16 COMMINS	94	$^{205}\text{TI}$ beams
- 27 ± 83		16 ABDULLAH	90	$^{205}\text{TI}$ beams
- 1400 ± 2400		CHO	89	TI F molecules
- 150 ± 550 ± 150		MURTHY	89	Cesium, no <i>B</i> field
- 5000 ± 11000		LAMOREAUX	87	$^{199}\text{Hg}$
19000 ± 34000	90	SANDARS	75	Thallium
7000 ± 22000	90	PLAYER	70	Xenon
< 30000	90	WEISSKOPF	68	Cesium

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- <sup>14</sup> HUDSON 11 gives a measurement corresponding to this limit as  $(-2.4 \pm 5.7 \pm 1.5) \times 10^{-28}$  ecm.  
<sup>15</sup> ECKEL 12 gives a measurement corresponding to this limit as  $(-1.07 \pm 3.06 \pm 1.74) \times 10^{-25}$  ecm.  
<sup>16</sup> ABDULLAH 90, COMMINS 94, and REGAN 02 use the relativistic enhancement of a valence electron's electric dipole moment in a high-Z atom.

## e<sup>-</sup> MEAN LIFE / BRANCHING FRACTION

A test of charge conservation. See the "Note on Testing Charge Conservation and the Pauli Exclusion Principle" following this section in our 1992 edition (Physical Review **D45** S1 (1992), p. VI.10).

Most of these experiments are one of three kinds: Attempts to observe (a) the 255.5 keV gamma ray produced in  $e^- \rightarrow \nu_e \gamma$ , (b) the (K) shell x ray produced when an electron decays without additional energy deposit, e.g.,  $e^- \rightarrow \nu_e \bar{\nu}_e \nu_e$  ("disappearance" experiments), and (c) nuclear de-excitation gamma rays after the electron disappears from an atomic shell and the nucleus is left in an excited state. The last can include both weak boson and photon mediating processes. We use the best  $e^- \rightarrow \nu_e \gamma$  limit for the Summary Tables.

Note that we use the mean life rather than the half life, which is often reported.

### e → ν<sub>e</sub>γ and astrophysical limits

VALUE (yr)	CL%	DOCUMENT ID	TECN	COMMENT
>4.6 × 10 <sup>26</sup>	90	BACK 02	BORX	$e^- \rightarrow \nu \gamma$
<b>• • •</b> We do not use the following data for averages, fits, limits, etc. <b>• • •</b>				
>1.22 × 10 <sup>26</sup>	68	17 KLAUDOR-K... 07	CNTR	$e^- \rightarrow \nu \gamma$
>3.4 × 10 <sup>26</sup>	68	BELLI 00B	DAMA	$e^- \rightarrow \nu \gamma$ , liquid Xe
>3.7 × 10 <sup>25</sup>	68	AHARONOV 95B	CNTR	$e^- \rightarrow \nu \gamma$
>2.35 × 10 <sup>25</sup>	68	BALYSH 93	CNTR	$e^- \rightarrow \nu \gamma$ , <sup>76</sup> Ge detector
>1.5 × 10 <sup>25</sup>	68	AVIGNONE 86	CNTR	$e^- \rightarrow \nu \gamma$
>1 × 10 <sup>39</sup>		18 ORITO 85	ASTR	Astrophysical argument
>3 × 10 <sup>23</sup>	68	BELLOTTI 83B	CNTR	$e^- \rightarrow \nu \gamma$

<sup>17</sup> The authors of A. Derbin et al, arXiv:0704.2047v1 argue that this limit is overestimated by at least a factor of 5.

<sup>18</sup> ORITO 85 assumes that electromagnetic forces extend out to large enough distances and that the age of our galaxy is  $10^{10}$  years.

### Disappearance and nuclear-de-excitation experiments

VALUE (yr)	CL%	DOCUMENT ID	TECN	COMMENT
>6.4 × 10 <sup>24</sup>	68	19 BELLI 99B	DAMA	De-excitation of <sup>129</sup> Xe
<b>• • •</b> We do not use the following data for averages, fits, limits, etc. <b>• • •</b>				
>4.2 × 10 <sup>24</sup>	68	BELLI 99	DAMA	Iodine L-shell disappearance
>2.4 × 10 <sup>23</sup>	90	20 BELLI 99D	DAMA	De-excitation of <sup>127</sup> I (in NaI)
>4.3 × 10 <sup>23</sup>	68	AHARONOV 95B	CNTR	Ge K-shell disappearance
>2.7 × 10 <sup>23</sup>	68	REUSSER 91	CNTR	Ge K-shell disappearance
>2 × 10 <sup>22</sup>	68	BELLOTTI 83B	CNTR	Ge K-shell disappearance
<sup>19</sup> BELLI 99B limit on charge nonconserving $e^-$ capture involving excitation of the 236.1 keV nuclear state of <sup>129</sup> Xe; the 90% CL limit is $3.7 \times 10^{24}$ yr. Less stringent limits for other states are also given.				
<sup>20</sup> BELLI 99D limit on charge nonconserving $e^-$ capture involving excitation of the 57.6 keV nuclear state of <sup>127</sup> I. Less stringent limits for the other states and for the state of <sup>23</sup> Na are also given.				

## LIMITS ON LEPTON-FLAVOR VIOLATION IN PRODUCTION

Forbidden by lepton family number conservation.

This section was added for the 2008 edition of this *Review* and is not complete. For a list of further measurements see references in the papers listed below.

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<8.9 × 10 <sup>-6</sup>	95	AUBERT 07P	BABR	$e^+ e^-$ at $E_{\text{cm}} = 10.58$ GeV
<b>• • •</b> We do not use the following data for averages, fits, limits, etc. <b>• • •</b>				
<1.8 × 10 <sup>-3</sup>	95	GOMEZ-CAD... 91	MRK2	$e^+ e^-$ at $E_{\text{cm}} = 29$ GeV

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$\sigma(e^+e^- \rightarrow \mu^\pm\tau^\mp) / \sigma(e^+e^- \rightarrow \mu^+\mu^-)$ 

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<4.0 \times 10^{-6}$	95	AUBERT	07P	BABR $e^+e^-$ at $E_{cm} = 10.58$ GeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<6.1 \times 10^{-3}$	95	GOMEZ-CAD...	91	MRK2 $e^+e^-$ at $E_{cm} = 29$ GeV

## e REFERENCES

ECKEL	12	PRL 109 193003	S. Eckel, A.O. Sushkov, S.K. Lamoreaux (YALE)	REFID=54628
Mohr	12	RMP 84 1527	P.J. Mohr, B.N. Taylor, D.B. Newell (NIST)	REFID=53956
HUDSON	11	NAT 473 493	J.J. Hudson <i>et al.</i> (LOIC)	REFID=53740
HANNEKE	08	PRL 100 120801	D. Hanneke, S. Fogwell, G. Gabrielse (HARV)	REFID=52434
MOHR	08	RMP 80 633	P.J. Mohr, B.N. Taylor, D.B. Newell (NIST)	REFID=52197
AUBERT	07P	PR D75 031103	B. Aubert <i>et al.</i> (BABAR Collab.)	REFID=51687
KLAPDOR-K...	07	PL B644 109	H.V. Klapdor-Kleingrothaus, I.V. Krivosheina, I.V. Titkova (HARV)	REFID=51596;ERROR=1
ODOM	06	PRL 97 030801	B. Odom <i>et al.</i> (HARV)	REFID=51358
MOHR	05	RMP 77 1	P.J. Mohr, B.N. Taylor (NIST)	REFID=49695
BACK	02	PL B525 29	H.O. Back <i>et al.</i> (BOREXINO/SASSO Collab.)	REFID=48528
BEIER	02	PRL 88 011603	T. Beier <i>et al.</i>	REFID=48516
REGAN	02	PRL 88 071805	B.C. Regan <i>et al.</i>	REFID=48608
BELLI	00B	PR D61 117301	P. Belli <i>et al.</i> (DAMA Collab.)	REFID=47628
BELLI	99	PL B460 236	P. Belli <i>et al.</i> (DAMA Collab.)	REFID=47060
BELLI	99B	PL B465 315	P. Belli <i>et al.</i> (DAMA Collab.)	REFID=47246
BELLI	99D	PR C60 065501	P. Belli <i>et al.</i> (DAMA Collab.)	REFID=47560
MOHR	99	JPCRD 28 1713	P.J. Mohr, B.N. Taylor (NIST)	REFID=47256
Also		RMP 72 351	P.J. Mohr, B.N. Taylor (NIST)	REFID=47373
AHARONOV	95B	PR D52 3785	Y. Aharonov <i>et al.</i> (SCUC, PNL, ZARA+)	REFID=44454
Also		PL B353 168	Y. Aharonov <i>et al.</i> (SCUC, PNL, ZARA+)	REFID=44387
FARNHAM	95	PRL 75 3598	D.L. Farnham, R.S. van Dyck, P.B. Schwinberg (WASH)	REFID=44548
SCHAFFER	95	PR A51 838	A. Schaefer, J. Reinhardt (FRAN)	REFID=45975
COMMINS	94	PR A50 2960	E.D. Commins <i>et al.</i>	REFID=45949
BALYSH	93	PL B298 278	A. Balysh <i>et al.</i> (KIAE, MPIH, SASSO)	REFID=43285
Fee	93	PR A48 192	M.S. Fee <i>et al.</i>	REFID=46777
HUGHES	92	PRL 69 578	R.J. Hughes, B.I. Deutch (LANL, AARH)	REFID=42139
MUELLER	92	PRL 69 3432	B. Muller, M.H. Thoma (DUKE)	REFID=43158
PDG	92	PR D45 S1	K. Hikasa <i>et al.</i> (KEK, LBL, BOST+)	REFID=41900
GOMEZ-CAD...	91	PRL 66 1007	J.J. Gomez-Cadenas <i>et al.</i> (SLAC MARK-2 Collab.)	REFID=41469
REUSSER	91	PL B255 143	D. Reusser <i>et al.</i> (NEUC, CIT, PSI)	REFID=41453
ABDULLAH	90	PRL 65 2347	K. Abdullah <i>et al.</i> (LBL, UCB)	REFID=41395
CHO	89	PRL 63 2559	D. Cho, K. Sangster, E.A. Hinds (YALE)	REFID=41081
MURTHY	89	PRL 63 965	S.A. Murthy <i>et al.</i> (AMHT)	REFID=41047
COHEN	87	RMP 59 1121	E.R. Cohen, B.N. Taylor (RISC, NBS)	REFID=11616
LAMOREAUX	87	PRL 59 2275	S.K. Lamoreaux <i>et al.</i> (WASH)	REFID=41048
VANDYCK	87	PRL 59 26	R.S. van Dyck, P.B. Schwinberg, H.G. Dehmelt (WASH)	REFID=40305
VASSERMAN	87	PL B198 302	I.B. Vasserman <i>et al.</i> (NOVO)	REFID=40311
Also		PL B187 172	I.B. Vasserman <i>et al.</i> (NOVO)	REFID=40312
AVIGNONE	86	PR D34 97	F.T. Avignone <i>et al.</i> (PNL, SCUC)	REFID=10111
ORITO	85	PRL 54 2457	S. Orito, M. Yoshimura (TOKY, KEK)	REFID=40529
CHU	84	PRL 52 1689	S. Chu, A.P. Mills, J.L. Hall (BELL, NBS, COLO)	REFID=40549
BELLOTTI	83B	PL 124B 435	E. Bellotti <i>et al.</i> (MILA)	REFID=10109
SCHWINBERG	81	PRL 47 1679	P.B. Schwinberg, R.S. van Dyck, H.G. Dehmelt (WASH)	REFID=10108
SANDARS	75	PR A11 473	P.G.H. Sandars, D.M. Sternheimer (OXF, BNL)	REFID=10100
COHEN	73	JPCRD 2 664	E.R. Cohen, B.N. Taylor (RISC, NBS)	REFID=10098
PLAYER	70	JPB 3 1620	M.A. Player, P.G.H. Sandars (OXF)	REFID=10092
WEISSKOPF	68	PRL 21 1645	M.C. Weisskopf <i>et al.</i> (BRAN)	REFID=10090

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